The Benthos of the Kosciusko Glacial Lakes

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Twenty-one macrobenthic species are recorded with a range of 8 to 12 species per lake. Common species include *Antipodrilus davidis*, the phreatoicid isopod *Metaphreatoicus australis, Chironomus ?oppositus* and *Pisidium tasmanicum*. The latter three species together with an unidentified gammarid amphipod are typical of highland lakes in south-eastern Australia. Relative numbers and distribution in the lakes appear to be influenced by fish predation.

Momentary biomass levels range from 2.4-14.9 g m^{-2} and in some lakes benthic production must be based largely on allochthonous organic matter.

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INTRODUCTION

Blue Lake, near Mt. Kosciusko, was one of the first Australian lakes to be dredged for benthic invertebrates; Hedley took samples from 28m there sometime during 1905/6. Descriptions of three worms (*Antipodrilus davidis, Branchiura pleurotheca* (= *Rhycodrilus coccineus*), *Phreodriloides notabilis*) and two endemic molluscs (*Glacidorbis hedleyi, Glacipisium kosciusko*) were subsequently published (Benham, 1907 and Iredale, 1943, respectively). There have been few further investigations on Blue Lake and the other nearby lakes (Cootapatamba, Albina and Club) despite their being the only glacial lakes in mainland Australia, and the highest in altitude (1890m, 2070m, 1920m, 1950m, respectively) in all Australia. Information is available on their physiography (Dulhunty, 1945), water chemistry (Williams, Walker and Brand, 1970), phytoplankton (Powell, 1970), zooplankton (Bayly, 1970) and on some other invertebrate inhabitants (e.g. Ball, 1977; Hynes and Hynes, 1975).

The present paper is concerned with the composition, diversity and standing crops of the benthic invertebrates of the lakes. Only the herpobenthos was sampled and attention was focused on macro-invertebrates. This paper is one of a series on the benthos of Australian lakes, aspects of which have recently been reviewed by Martin and Timms (1978), and Timms (in press).

METHODS

The lakes were visited during February 7-11, 1976. Sampling stations were chosen in each lake to represent the area and depth range as adequately as possible. In Blue Lake there were 7 stations at roughly 4m depth intervals from 1 to 26m. There were 8 stations in Lake Albina, 4 in each basin. Five stations were used in Cootapatamba but only two in the small Club Lake.

At each site quadruplicate samples were collected with a Birge Ekman grab of 200 cm^2 gape and sieved through mesh of aperture 0.4 mm. The organisms retained were sorted alive in the field and then preserved in 70% alcohol. This results in up to a 10% weight loss (Weiderholm and Erikson, 1977). In the laboratory the number of individuals of each species and the wet biomass of each taxonomic group were determined for each sample. In the preparation of samples for weighing, excess external water was blotted and the shells of molluscs removed beforehand. A mean weighted biomass was calculated for each lake by integration using bathymetric charts given in Dulhunty (1945).

Samples of the substrate were taken from the deepest station in each lake and stored at 5°C before drying. Then they were analysed for organic matter by % loss on ignition at 550°C and for %C and %N by the CSIRO Microanalytical Service.

Some Physicochemical Features of the Lakes

The water of all four lakes is very fresh (salinity < 3 ppm) with a pH near 6 (Williams, Walker and Brand, 1970). Their water is transparent (eg. Secchi disc depth of *ca* 6m in Blue Lake). Seasonal temperature regimes are unknown, but all four freeze over for several months during winter; Blue Lake was stratified (11°C at surface and 8°C at 12m), Albina was weakly stratified while the two shallow lakes, Lake Cootapatama and Club Lake, were isothermal when visited in February. Thus at least two of the Kosciusko glacial lakes are of the warm thereimictic type (see Bayly & Williams, 1973) while Blue Lake is possibly dimictic and as such would be the only known example of this type on mainland Australia, though examples occur in highland Tasmania (P. Tyler, personal communication). There were no indications of hypolimnetic oxygen deficiencies in Blue or Albina.

TABLE 1

Some chemical characteristics of the lake muds

Lakes	Sample depth (m)	Organic Matter %	Carbon %	Nitrogen %	C/N ratio
Blue	26	12.1	5.21	0.56	9.30
Club	2	7.1	2.44	0.36	6.77
Albina	8.5	23.1	11.59	0.80	14.48
Cootapatamba	3	16.5	6.49	0.73	8.89

Bottom substrates were largely sandy-grit to sandy-mud in Lake Cootapatamba (except at stations > 2m) and at stations <1m in Club Lake and Lake Albina, and <5m in Blue Lake. In the latter visible organic detritus was particularly obvious in the 8 and 12m stations. Deeper stations in all lakes were of fine organic mud. Muds from the deepest stations in each lake had organic matter contents ranging from 7.1 - 23.1%, carbon contents 2.4 - 11.6% and nitrogen levels 0.36 - 0.80% (Table 1). Carbon/nitrogen ratios are <10 in Blue Lake, Club Lake and Lake Cootapatamba, but in Lake Albina the ratio is much higher (14.5) indicating considerable input of allochthonous organic matter (Hansen, 1959). The source of at least some of this could well be septic effluent from Albina Hut.

Results

(a) *Blue Lake.* Twelve macrobenthic species were recorded from Blue Lake; the dominants were *Antipodrilus davidis, Chironomus ?oppositus* and *Glacipisidium kosciusko* (Table 2). At least two mesobenthic species — the ostracod *Candonocypris* n. sp. and the mite *Oxus australicus* Lundblad live associated with the bottom.

Number of species, abundance and biomass were greatest in the sub-littoral (Table 2). Despite the lake being relatively deep, there were no species restricted to the profundal, the common species there being the dominants. Mean weighted biomass was 12.3 g m^{-2}, with chironomids the most important contributor (63%) and oligochaetes next (25%).

TABLE 2

Blue Lake benthos — species present, their abundance (as individuals m^{-2}) and biomass with depth.

Species	1m	4m	8m	12m	16m	20m	26m
unidentified large nematode	—	—	11	—	—	—	—
Antipodrilus davidis } Tubificidae n. gen.	177	499	1232	965	810	1209	477
Metaphreatoicus australis	—	11	399	11	11	—	—
Procladius sp.	—	11	78	33	11	11	33
Polypedilum nr *tonnoiri*	—	—	11	22	—	—	—
Chironomus ?oppositus	1132	3274	3951	3152	3340	2642	2120
Tasmanophebia nigrescens	—	11	—	—	—	—	—
Ramrheithrus dubitans	11	22	—	—	11	—	—
unidentified tipulid larva	22	—	—	—	—	—	—
Glacidorbis hedleyi	—	11	—	—	—	—	—
Glacipisium kosciusko	44	1100	1643	1798	739	480	242
Total Numbers (individual m^{-2})	1386	4939	7325	5981	4922	4342	2872
Total Biomass (g m^{-2})	3.67	14.72	23.49	14.40	11.49	12.17	7.05

(b) *Club Lake*. Eight macrobenthic (Table 3) and three mesobenthic species (*Candonocypris* n. sp., the cladoceran *Biapertura affinis* and the copepod *Macrocyclops albidus*) were noted in the 8 grabs. *Chironomus ?oppositus* was dominant while *Pisidium tasmanicum* and unidentified turbellarian were common.

Mean weighted biomass was 2.4 g m^{-2} with chironomids the most significant contributor (60%).

TABLE 3

Club Lake benthos — species present, their abundance (as individuals m^{-2}) and biomass with depth.

Species	1m	2m
unidentified green turbellarian	855	355
unidentified large nematode	66	177
Antipodrilus davidis	344	89
Metaphreatoicus australis	—	11
Procladius sp.	33	111
Chironomus ?oppositus	1432	4074
Glacidorbis hedleyi	11	—
Pisidium tasmanicum	455	333
Total Numbers (as individual m^{-2})	3196	5150
Total Biomass (as g m^{-2})	2.30	3.12

(c) *Lake Albina*. Both basins yielded nine species (Table 4). There were no significant differences in distribution patterns between the basins or at different depths. The phreatoicid isopod *Metaphreatoicus australis* and *Pisidium tasmanicum* were dominant, while *Antipodrilus davidis, Procladius villosimanus* and *Tanytarsus paskervillensis* were relatively important.

Isopods were the main contributor (91%) to the mean weighted biomass of 14.9 g m^{-2}.

(d) *Lake Cootapatamba*. Ten macrobenthic species and *Candonocypris* n. sp., were noted in the 20 grabs (Table 5). The dominant species numerically was *Antipodrilus davidis;* it and other common species including *Metaphreatoicus australis* and *Pisidium tasmanicum* occurred at all depths sampled.

TABLE 4

Lake Albina benthos — species present, their abundance (as individuals m^{-2}) and biomass with depth.

	South Basin				North Basin			
Species	0.5m	1m	2m	3.5m	3m	5m	6.5m	8.5m
Spathula truculenta	11	33	—	—	11	33	22	55
Antipodrilus davidis	22	11	311	644	344	455	888	533
unidentified gammarid amphipod	11	—	—	—	11	11	710	67
Metaphreatoicus australis	722	2387	1199	1265	444	533	1276	1210
Procladius villosimanus	56	244	400	588	211	211	255	233
Tanytarsus paskervillensis	—	11	200	544	322	11	11	33
Chironomus ?oppositus	—	—	44	56	33	66	122	89
Glacidorbis hedleyi	—	—	22	—	22	—	—	55
Pisidium tasmanicum	33	599	737	333	732	866	2309	3109
Total Numbers (individual m^{-2})	855	3285	2913	3430	2130	2186	5593	5384
Total Biomass ($g\ m^{-2}$)	9.92	30.64	12.72	21.66	7.33	9.02	36.98	26.70

TABLE 5

Lake Cootapatamba benthos — species present, their abundance (as individuals m^{-2}) and biomass with depth.

Species	0.5m	1m	1.5m	2.2m	3m
unidentified green turbellarian	—	11	—	—	—
Antipodrilus davidis, Tubificidae n. gen., *Dero furcatus*	1565	3052	577	1121	133
unidentified gammarid amphipod	477	55	155	78	67
Metaphreatoicus australis	388	178	311	444	200
Procladius villosimanus	—	—	11	33	56
Tanytarsus sp.	—	100	122	400	200
Chironomus ?oppositus	—	—	—	11	—
Austreithrus sp.	11	—	—	—	—
Pisidium tasmanicum	144	325	335	389	267
Total Numbers (individual m^{-2})	2585	3721	1511	2476	923
Total Biomass ($g\ m^{-2}$)	10.37	9.13	10.33	9.77	5.64

Mean weighted biomass was 9.5 $g\ m^{-2}$, with isopods the most important (71%) and oligochaetes next (21%).

DISCUSSION

(a) *Community Structure.* Twenty-one macrobenthic species were collected from the four lakes, with a range of 8 to 12 in each (Table 6). Typically each lake contained a turbellarian, an oligochaete, an isopod, two to three chironomids including *Chironomus ?oppositus,* a snail and a sphaerid bivalve. This low diversity is typical of lakes in Australia (Timms, in press) but it is even less than "average" (cf. mean of 16.6 species in 16 lakes in lowland of south-eastern Australia and 21.3 in 7 Tasmanian lakes — Timms, 1978). Possible reasons for the general situation are given in Timms (in press), while in the case of the Kosciusko lakes, factors such as physicochemical harshness and small size (and hence high homogeneity) could restrict diversity further.

Most species listed in Tables 2-6 have been recorded from the area before, many as stream dwellers, e.g. the crustaceans, mayfly and caddisflies. In that the

TABLE 6

Presence and relative abundance of macrobenthic species in the Kosciusko Lakes. (Key: + + + + = very common, + + + = common, + + = present; and + = uncommon).

Species	Blue Lake	Club Lake	Lake Albina	Lake Cootapatamba
Platyhelminthes				
Spathula truculenta Ball			+	
unidentified green turbellarian		+ + +		+
Nematoda				
unidentified large nematode	+	+ +		
Oligochaeta				
Antipodrilus davidis }	+ + +	+ +	+ + +	
Tubificidae n. gen. }				} + + + +
Dero furcatus (Müller)				
Crustacea				
Metaphreatoicus australis	+	+	+ + + +	+ + +
unidentified gammarid amphipod			+ +	+ +
Insecta: Ephemeroptera				
Tasmanophlebia nigrescens Till.	+			
Insecta: Trichoptera				
Austrheithrus dubitans Mos.				+
Ramrheithrus sp.	+			
Insecta: Diptera				
Procladius villosimanus Kieffer			+ + +	+
Procladius sp.	+	+ +		
Tanytarsus paskervillensis Glover			+ +	
Tanytarsus sp.				+ +
Polypedilium nr. *tonnoiri* Freeman	+			
Chironomus ?oppositus Walker	+ + + +	+ + + +	+ +	+
unidentified tipulid larva	+			
Mollusca				
Glacidorbis hedleyi Iredale	+	+	+	
Glacipisium kosciusko Iredale	+ + +			
Pisidium tasmanicum Ten. Wood		+ + +	+ + +	+ +

inadequately described *Glacipisium kosciusko* appears to be synonymous with *Pisidium tasmanicum*, the presence of the latter is not new. Two notable absences are Benham's worms, *Rhycodrilus coccineus* and *Phreodriloides notabilis* which must be uncommon and easily overlooked or no longer present.

At least three new species have been found — a tubificid worm, a candonocyprid ostracod, and a gammarid amphipod. They are to be described in due course by the appropriate taxonomists (see acknowledgements).

Although there is a core of species common to all lakes, there is a marked difference in the distribution and relative abundance of some species between Blue and Club Lakes in which the mountain minnow *Galaxias findlayi* is common and Lakes Albina and Cootapatamba which lack fish (Table 6). To illustrate, *Chironomus ?oppositus* is abundant, *Metaphreatoicus australis* uncommon and the gammarid amphipod not present in the benthos of Blue and Club Lakes, while in Lakes Albina and Cootapatamba, *Chironomus ?oppositus* is uncommon, *Metaphraetoicus australis* very common and the amphipod is present. A continuing study on the littoral fauna of the lakes (Timms, unpublished) is revealing other differences in the distribution and relative numbers of invertebrates and tadpoles in the two lake groups, while Hebert (1977) notes the absence of the large planktonic cladoceran, *Daphnia nivalis* (syn. *D. alpina*) from the two lakes with fish. It seems then, that predation by fish is an important determinant of community structure in these lakes, as it is some lakes elsewhere (eg. Tuunainen, 1970).

(b) *Zoogeography.* Of the species identified only a few (e.g. *Procladius villosimanus, Antipodrilus davidis*) are common components of benthic communities of Australian lakes. Five species, *Metaphreatoicus australis, Tasmanophlebia nigrescens, Austrheithrus dubitans, Spathula truculenta,* and *Glacidorbis hedleyi* are restricted to the highlands of south-eastern Australia. There appear to be no endemic species, unless the undescribed or unidentified species are.

All the dominant species (*Metaphreatoicus australis, Chironomus ?oppositus, Pisidium tasmanicum*) and many of the common ones belong to a group important in Lake Tarli Karng (the only other deep lake in the highlands of southeast mainland Australia; Timms, 1974) and in the highland Tasmanian lakes investigated by Timms (1978). This reinforces the biographical relationships between the highland areas of south-eastern Australia noted for other communities.

(c) *Biomass.* Taken that the mean biomass figures for the lakes are not annual means, but momentary values, and that the figures for Lakes Cootapatamba and Albina may be elevated due to lack of fish predation (by up to a factor of 2 — Kajak, 1972) the figures for all lakes except Club are unexpectedly high for lakes which on other criteria (e.g. water chemistry, sparse phytoplankton) appear oligotrophic. It seems this is because benthic production is based largely on allochthonous organic matter input (cf. Bretschko, 1975).

Although no data are available on organic matter input, particulate input must be significant at least in Blue Lake and Lake Albina where partly decomposed leaves and twigs were commonly recovered from samples; additionally in Lake Albina, the septic effluent from Albina Hut probably adds organic matter. Percent organic matter is greatest in Lake Albina mud where the C/N ratio indicates considerable input of allochthonous matter and least in Club Lake where the flushing of the lake prevents any accumulation. Mean biomass figures apparently reflect the levels of organic matter in the four lakes (Table 7). However the correlation is not statistically significant ($r = 0.840$ $P = 0.05$). By comparison, some other lakes at high altitudes in southeastern Australia e.g. Lakes St. Clair, Dobson, Tarli Karng (Timms, 1974, 1978) also have considerable allochthonous organic matter input and associated higher benthic standing crops than expected on other criteria.

The dominant contributors to biomass in each lake are surface feeding detritivores — *Metaphreatoicus australis* in Lakes Cootapatamba and Albina and *Chironomus ?oppositus* in Blue and Club Lakes. Oligochaetes and molluscs (almost

TABLE 7

Percentage contribution to total biomass by species according to eight taxonomic groupings.

Parameter	Cootapatamba	Albina	Club	Blue
% organic matter in mud	16.5	23.1	7.1	12.1
Mean Standing Crop (g/m^2)	9.48	14.87	2.44	12.31
% contribution to biomass				
Planarians	0.1	0.1	12.2	
Oligochaetes	20.5	3.5	14.2	24.5
Phreatoicids	70.6	91.3	0.4	4.0
Amphipods	6.4	1.1		
Chironomids	0.4	2.7	59.7	62.9
Snails		0.1		0.1
Bivalves	1.8	1.2	12.9	7.8
Others	0.2		0.6	0.7

entirely of sphaerid bivalves) are relatively important in at least two lakes (Table 7). It is the importance of *Chironomus ?oppositus*, crustaceans and sphaerid bivalves which characterize the Kosciusko glacial lakes, separating them from lakes of lowland eastern Australia where these taxa are absent or unimportant (Timms, in press) and even from highland Tasmanian lakes, where although *Chironomus ?oppositus* and crustaceans are often important, sphaerid bivalves usually are not (Timms, 1978).

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